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Use of Selected Sorbents and an Aqueous Film Forming Foam on Floating Hazardous Materials

Mason and Hanger-Silas Mason Co., Inc.
Leonardo, NJ

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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EPA-600/2-81- 211
September 1981

USE OF SELECTED SORBENTS AND AN AQUEOUS FILM FORMING FOAM ON FLOATING HAZARDOUS MATERIALS

by

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Contract No. 68-03-0490

Project Officer

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OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
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16. ABSTRACT

This research test program was initiated by the U.S. Environmental Protection Agency (EPA) to determine the effect sorbent materials and fire fighting foam have on containment, recovery and vapor suppression of floatable hazardous materials(HM) spilled on water.

The test plan incorporates some of the equipment used during a 1975 U.S. EPA hazardous materials test at the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT). The devices used in both programs were the Clean Water Incorporated Harbour Boom and the Industrial and Municipal Engineering Swiss OELA III Skimmer. Dioctyl phthalate(DOP), octanol, and naphtha served as the hazardous materials. The sorbent materials were polyurethane foam cubes, Clean Water, Inc. Sorbent C and Dow Chemical Co. Imbiber Beads. An aqueous film forming foam(AFFF), FC-206, from 3M Company was used as the fire fighting foam.

The type of HM, Sorbent, tow speed, and wave condition served as controlled and independent variables. Critical tow speed of the boom (the speed at which oil loss began), HM vapor concentration, and fluid recovered by the skimmer were the dependent variables. Results of the tests were evaluated in terms of the differences in these dependent variables when sorbents and foams were distributed on the HM slick versus a pure HM slick.

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report describes testing of aqueous film forming foams (AFFF) and sorbents used in conjunction with several spill clean-up devices to remove floating hazardous material from water. The tests examined the effects of the AFFF and sorbents on the performance of the clean-up devices. Some tests were also conducted to determine whether the sorbents and AFFF suppressed the formation of vapors above slicks of hazardous materials.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

ABSTRACT

This research test program was initiated by the U.S. Environmental Protection Agency (EPA) to determine the effect sorbent materials and fire fighting foam have on containment, recovery and vapor suppression of floatable hazardous materials (HM) spilled on water.

The test plan incorporates some of the equipment used during a 1975 U.S. EPA hazardous materials test at the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT).[1] The devices used in both programs were the Clean Water Incorporated Harbour Boom and the Industrial and Municipal Engineering Swiss OELA III Skimmer. Dioctyl phthalate (DOP), octanol, and naphtha served as the hazardous materials. The sorbent materials were polyurethane foam cubes, Clean Water, Inc. Sorbent C and Dow Chemical Co. Imbiber Beads. An aqueous film forming foam (AFFF), FC-206, from 3M Company was used as the fire fighting foam.

The type of HM, sorbent, tow speed, and wave condition served as controlled and independent variables. Critical tow speed of the boom (the speed at which oil loss began), HM vapor concentration, and fluid recovered by the skimmer were the dependent variables. Results of the tests were evaluated in terms of the differences in these dependent variables when sorbents and foams were distributed on the HM slick versus a pure HM slick.

Boom performance in all tests equalled or exceeded the 1975 tests, even those without sorbent or AFF foam. The highest no loss tow speed, (0.75 m/s), was obtained when polyurethane foam cubes were distributed on a naphtha slick.

This report was submitted in fulfillment of Job Order No. 35 by Mason & Hanger-Silas Mason Co., Inc., Leonardo, New Jersey under the sponsorship of the U.S. Environmental Protection Agency, Contract No. 68-03-0490. This report covers a period from 2 May 1977 to 13 May 1977 when work was completed.

---

1. McCracken, W.E. and S.H. Schwartz. Performance Testing of Spill Control Devices on Floatable Hazardous Materials. EPA-600/2-77-22, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. 139 pp.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

AFFF	--aqueous film forming foam
C	--Centigrade and calm water
cm	--centimeter
DOP	--dioctyl phthalate
EPA	--Environmental Protection Agency
F	--Fahrenheit
fluct.	--fluctuation
ft	--foot
gal	--gallon
gpm	--gallons per minute
HC	--harbor chop
HM	--hazardous material
HM/S	--hazardous material and sorbent
I.M.E.	--Industrial and Municipal Engineering
in	--inch
kg	--kilogram
kt	--knot
l	--liter
lb	--pound
m	--meter
min	--minute
mm	--millimeter
mph	--miles per hour
N	--Newton
OHMSETT	--Oil and Hazardous Materials Simulated Environmental Test Tank
ppm	--parts per million
ppt	--parts per thousand
psi	--pounds per square inch
PVC	--polyvinyl chloride
s	--second
TBD	--to be determined

SYMBOLS

C_{HM}	--concentration reading from hazardous material vapor inlet
$C_{HM/S}$	--concentration reading from hazardous material and sorbent vapor inlet
°	--degree
ΔC	--difference between C_{HM} and $C_{HM/S}$

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LIST OF CONVERSIONS

METRIC TO ENGLISH

To convert from	to	Multiply by
Celsius	degree Fahrenheit	$t_C = (t_F - 32)/1.8$
joule	erg	1.000 E+07
joule	foot-pound-force	7.374 E-01
kilogram	pound-mass (lbm avoir)	2.205 E+00
metre	foot	3.281 E+00
$metre_2$	$inch_2$	3.937 E+01
$metre_2$	$foot_2$	1.076 E+01
$metre_3$	$inch_3$	1.549 E+03
$metre_3$	gallon (U.S. liquid)	2.642 E+02
$metre^3$	litre	1.000 E+03
metre/second	foot/minute	1.969 E+02
metre/second	knot	1.944 E+00
$metre_2$/second	centistoke	1.000 E+06
$metre_3$/second	$foot^3$/minute	2.119 E+03
$metre^3$/second	gallon (U.S. liquid)/minute	1.587 E+04
newton	pound-force (lbf avoir)	2.248 E-01
watt	horsepower (550 ft lbf/s)	1.341 E-03

ENGLISH TO METRIC

centistoke	$metre^2$/second	1.000 E-06
degree Fahrenheit	Celsius	$t_C = (t_F - 32)/1.8$
erg	joule	1.000 E-07
$foot_2$	$metre_2$	3.048 E-01
$foot^2$	$metre^2$	9.290 E-02
foot/minute	metre/second	5.080 E-03
$foot^3$/minute	$metre^3$/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	$metre_3$	3.785 E-03
gallon (U.S. liquid)/minute	$metre^3$/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
$inch_2$	$metre_2$	2.540 E-02
$inch^2$	$metre^2$	6.452 E-04
knot (international)	metre/second	5.144 E-01
litre	$metre^3$	1.000 E-03
pound force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01
$pound/foot^2$	pascal	4.788 E+01

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ACKNOWLEDGMENTS

The cooperation of Clean Water, Inc. for supplying the Harbour Boom is sincerely appreciated.

Mr. J.S. Farlow is the Project Officer of OHMSETT, which is owned by the U.S. Environmental Protection Agency. His valuable assistance during the early stages of this project is gratefully acknowledged.

Dr. J.P. Lafornara, U.S.E.P.A., Project Officer for this test is gratefully acknowledged for his guidance and direction throughout the project. Dr. Lafornara's assistant, Mr. M.E. Lipsett, is sincerely thanked for his help in performing the vital vapor detection portion of the project.

Mason & Hanger-Silas Mason Co., Inc., is the operating contractor for OHMSETT. Mr. M.G. Johnson, of Mason & Hanger-Silas Mason Co., Inc., served as test director, and provided valuable suggestions throughout the test project. Appreciation is expressed to Mr. R.L. Swoyer for his engineering aid, to Messrs. S.G. Keadle and R.A. Dickson for the photo/video coverage of the tests, and to Mr. S.H. Schwartz for his editorial help.

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SECTION 1

INTRODUCTION AND OBJECTIVES

Large quantities of hazardous materials are constantly being handled by inland and marine transportation and support equipment. Spills during transit or at producer and user storage facilities pose a serious threat to the health and welfare of the general public and environment.

The U.S. EPA wished to investigate the possibility of enhancing present containment and recovery devices to compensate for adverse environmental conditions and vapors from HM which have a specific gravity less than water and are immiscible with water. Several concepts were considered feasible:

1. Increasing the cohesiveness of the spilled HM to stave off shedding[2] and splashover losses from a boom to a higher relative oil/water interface velocity and/or a greater wave impact.

2. Allowing the material to be absorbed into a more buoyant material could prevent submergence and shedding beneath a boom to a higher current velocity.

3. Covering the sorbent and hazardous material with fire fighting foam could decrease the vapors above the slick.

This last operation was considered essential since introducing a sorbent into the hazardous material could increase the vapor above the slick via wicking.

The purpose of this project was to investigate the effectiveness and practicality of the above mentioned concepts in a simulated field environment.

---

2. Bauer, W.H. and J.J. Bulloff. Chemical Additives to Control Oil Spills - A State of the Art Summary. DOT-CG-33, 755A, Department of Transportation, U.S. Coast Guard, Office of Research and Development, Washington, D.C., 1974. 58 pp.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions and recommendations were drawn from the evaluation of the test data and observations of equipment performance.

The sorbent material most easily distributed and accounted for later was the polyurethane foam cubes. The imbiber beads became very sticky after contact with oil and clung to every surface they touched. Sorbent C distribution caused large amounts of dust to be thrown into the air.

The application of sorbents or congealing agents to a floating HM spill is certainly possible using a simple blower-type distributor. Such a blower is used to distribute wood chips or straw to cover soil during landscaping operations.

The introduction of sorbents or congealing agents into the HM enables a stable boom to contain the material to a higher current velocity or tow speed in calm water. During the naphtha tests with foam cubes, the boom was brought up to its critical stabilization speed, 0.7 m/s, without shedding. This was an increase of 35% over the boom's limit of previous shedding threshold of 0.57 m/s without sorbent. The velocity at which shedding (Figure 1) occurs would be related to the amount of sorbent or congealing agent introduced and the thoroughness of interaction between it and the HM.

The sorbents and Imbiber Beads did not enhance containment in the presence of the 0.3 m harbor chop. Splashover failure (Figure 2) occurred from 0 to 0.05 m/s. Much larger amounts of congealing agent could have been used to enhance containment, but cleanup would have been very difficult. Such use would be costly in material and possibly damaging to the environment.

In order for the effect of the sorbents to be optimized, time for mixing and absorbtion of HM must be allowed. The time required will vary with the wave condition and turbulence caused by any current present. Applying the sorbent or imbiber beads to the surface of the slick as it approaches the boom does not sufficiently mix the materials.

The detectable vapor concentrations of octanol and DOP were found to be far less than the fluctuation in concentrations caused by uncontrolled factors (e.g., wind, temperatures). Therefore, no conclusions were drawn from the DOP and octanol vapor concentration data.

The changes in naphtha concentrations were in the same range as the fluctuations noted in control tests. Although the exact changes in concentrations are highly uncertain, it appears that no dramatic increase of naphtha vapor concentration occurred when sorbent was added to the floating HM.

RECOMMENDATIONS

Tests to determine the vapor concentrations over a HM slick with and without sorbents and AFFF should be conducted in a laboratory where temperature and wind effects can be precisely controlled.

Since the increase in the critical tow speed attained using sorbent cubes was so significant, further investigation should be done into the use of the "pockets of refuge" phenomenom which appears to retard oil shedding failure from booms.

Some investigation into the stabilizing effects of AFFF on oil in a boom should be done. Some test results show a higher critical tow speed was attained using AFFF with the sorbent than with the sorbent alone.

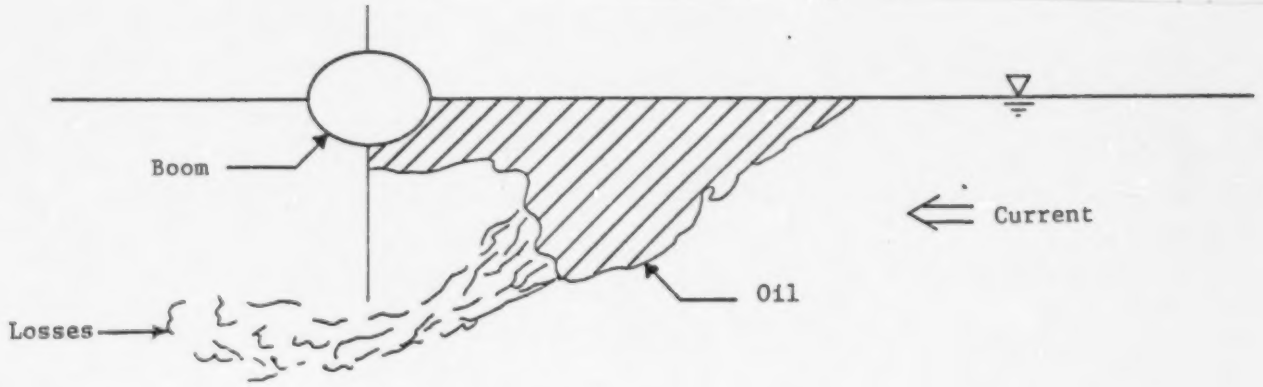


Figure 1. HM shedding failure and entrainment under a boom.

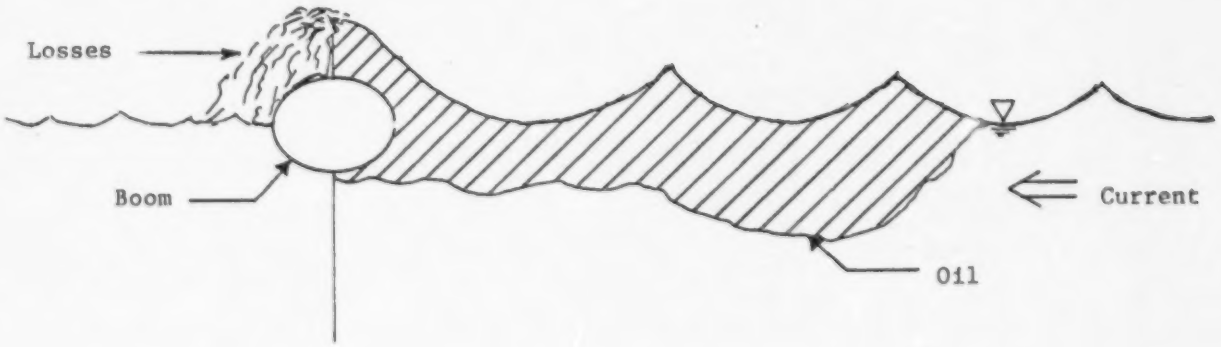


Figure 2. HM splashover failure over a boom.

SECTION 3

TEST AND EQUIPMENT DESCRIPTION

TEST APPARATUS ARRANGEMENT

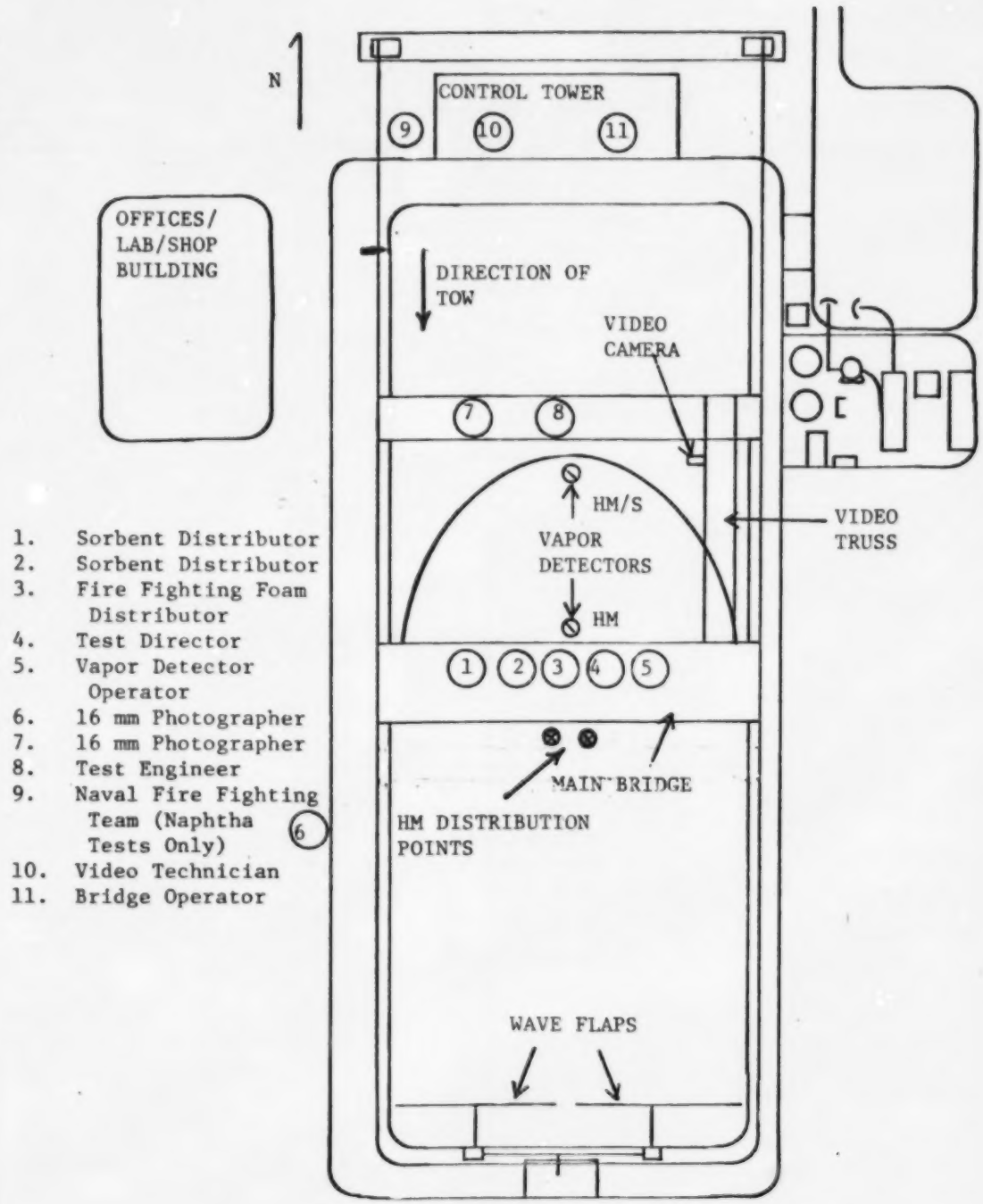
The Clean Water Harbour Boom was attached to the main bridge in the containment configuration for boom tests (Figure 3). In the 1975 test project, designed to test recovery devices for hazardous materials, the Clean Water Harbour Boom was used in a 60.5 m length. The video truss, which was subsequently built, spanned the main and observation bridges, limited the distance between the bridges to the length of the video truss, to 19.7 m for these tests. In order to observe the boom from behind the apex, a section of the boom had to be removed, reducing its length to 45.5 m. This did not noticeably alter boom performance. For skimmer tests, the bridge was brought to mid-tank, the skimmer placed in the water and the boom pulled to the west side of the tank to corral the HM for recovery (Figure 4).

The HM was stored in tanks on the main bridge and distributed into the boom from the south, center of the main bridge. As the test continued, sorbent and/or fire fighting foam was distributed onto the slick as it was passed over by the rear side of the main bridge. A gasoline-engine powered centrifugal blower with a 3 m long, 20 cm diameter flexible hose was used to apply the Sorbent C, Imbiber Beads and foam cubes. A rotary lawn fertilizer (vertical spreader axis) was first used to distribute the Imbiber Beads. A ½" variable speed drill was connected to the wheel axle and brought to the desired speed before the beads were added. The centrifugal blower performed better in that it could distribute beads farther at a greater rate. The fire fighting foam was applied from its container using a standard foam mixing nozzle connected to a fire hose.

BOOM DESCRIPTION

The Clean Water, Inc. Harbour Boom (Figure 5) was essentially the same boom used in the 1975 tests. Then, the skirt depth was 57 cm versus 61 cm today. The ends of the boom were bolted to the tow points of the main bridge, forming a catenary (containment) configuration under tow.

The boom proved very durable and fairly easy to steam-clean afterwards. The external covering of the boom is a nylon reinforced PVC sheet made specifically for oil contact. The upper tension member, which ran through the 15.24 cm diameter floats was a 1.27 cm diameter polypropylene line. The lower member, running in a pocket at the bottom of the skirt, was 0.63 cm hot-dipped galvanized high test chain. All fittings were either marine brass or hot-dipped galvanized.



1. Sorbent Distributor
2. Sorbent Distributor
3. Fire Fighting Foam Distributor
4. Test Director
5. Vapor Detector Operator
6. 16 mm Photographer
7. 16 mm Photographer
8. Test Engineer
9. Naval Fire Fighting Team (Naphtha Tests Only)
10. Video Technician
11. Bridge Operator

Figure 3. Test set-up and personnel requirements for boom tests.

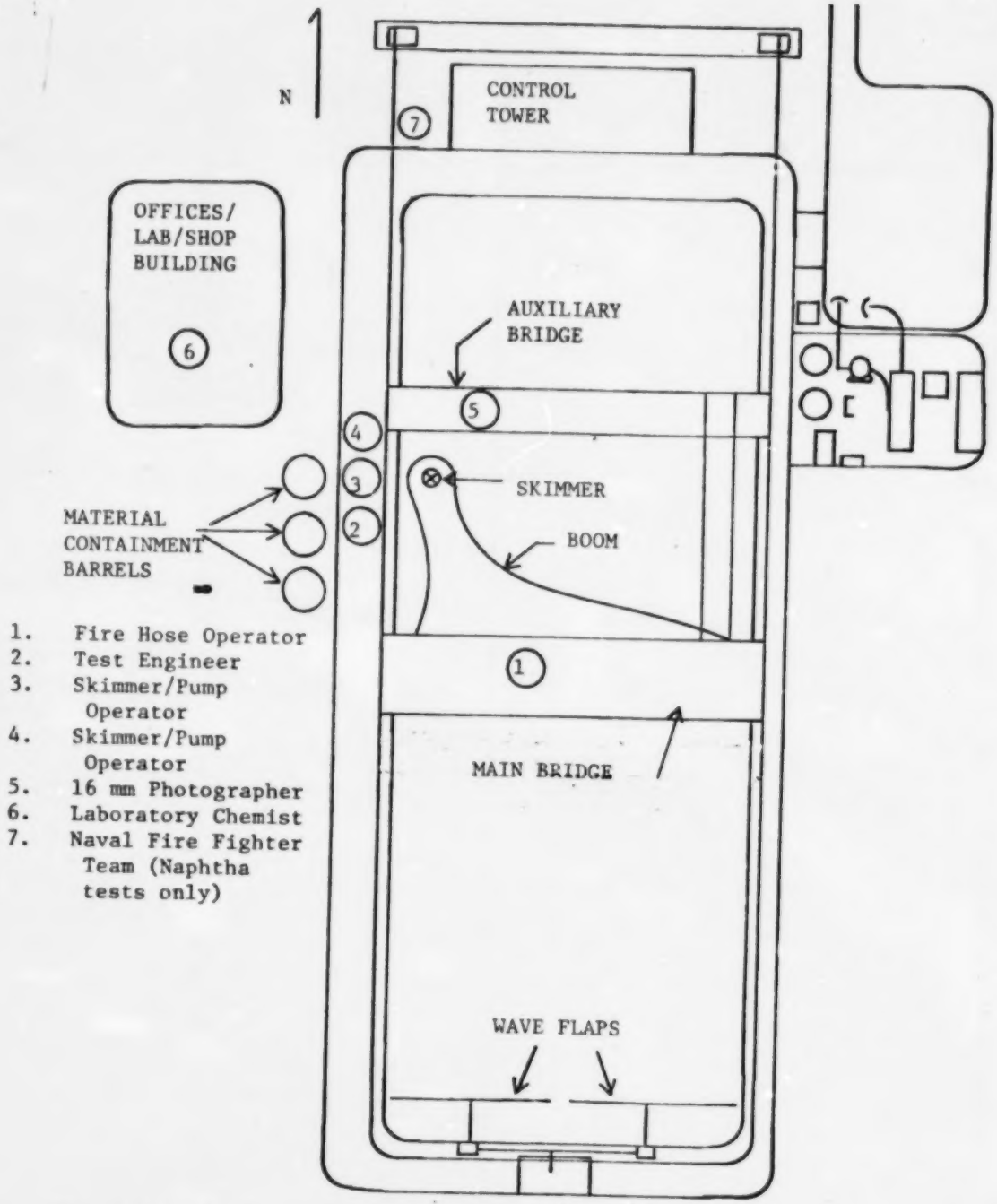


Figure 4. Test set-up and personnel requirements for skimmer tests.

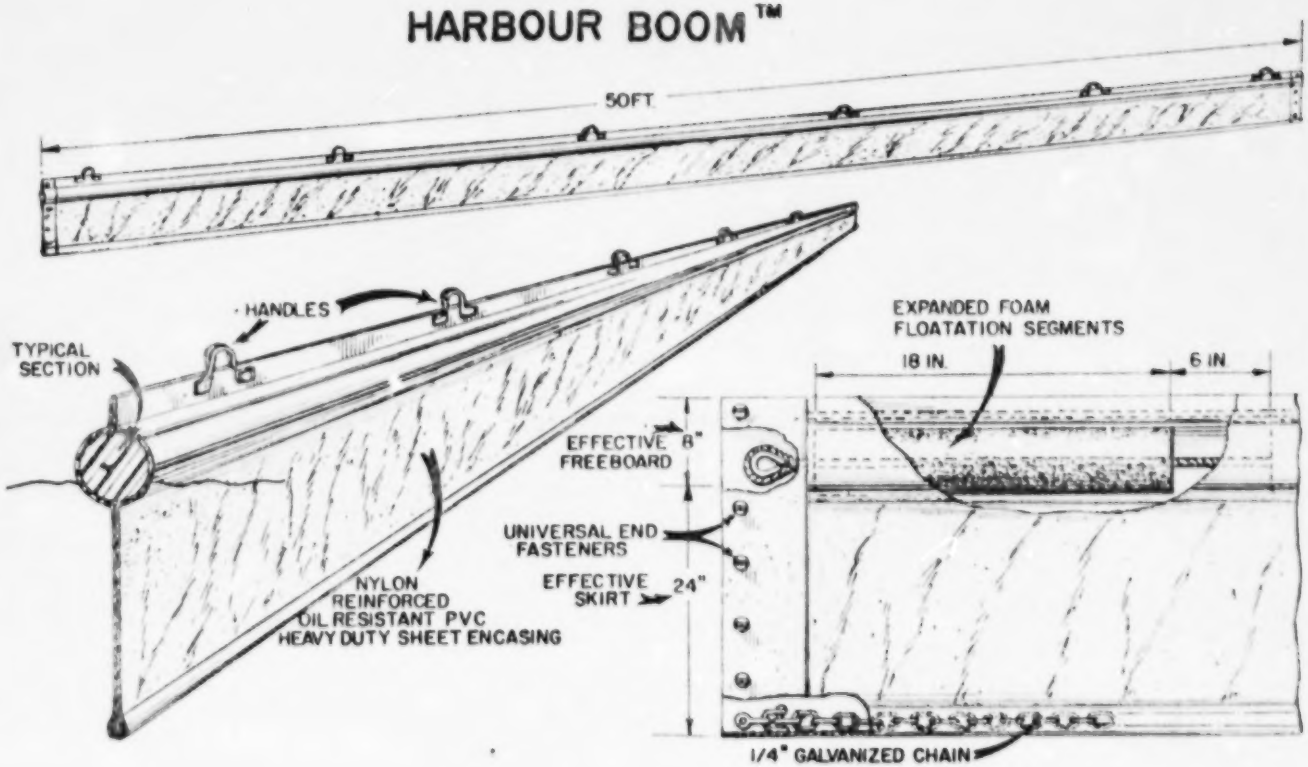


Figure 5. Diagram of Clean Water boom details.

SKIMMER DESCRIPTION

The Industrial and Municipal Engineering (I.M.E.) Swiss OELA III Skimmer was selected for this test because of its use in the 1975 test and its availability.

Design Characteristics

1. Height - 0.39 m
2. Weight - 49.9 kg
3. Capacity - 19 l/s

A double diaphragm, Warren Rupp Sandpiper pump (Model SA-3A, Type DA2-A), was used until clogging problems occurred. A 5.1 cm inlet/outlet Barnes rotary pump driven by a 2-3/4 HP Wisconsin gasoline engine was then employed. Except for priming problems when the skimmer emptied, and air was pumped, it performed satisfactorily and without clogging.

The I.M.E. skimmer was connected to the pump via a 15.2 m long, 5.1 cm diameter flexible hose, coupled with camlock fittings. The pump discharged into the collection barrels through a 9.0 m long, 5.1 cm diameter flexible hose.

VIDEO AND PHOTOGRAPHIC DOCUMENTATION

Cameras provided visual documentation of test layout, equipment, and performance characteristics. A black and white TV camera in a waterproof case provided underwater video coverage, which was recorded on 2.54 cm video tape using a recording deck. Topside and tankside window coverage was provided by two 16 mm movie cameras and a 35 mm slide camera.

TEST FLUID DESCRIPTION

Naphtha, DOP, and octanol were the hazardous materials selected for this and the 1975 test program. These test fluids represented a wide range of three important physical properties-- viscosity, specific gravity and interfacial tension. The HM were also selected for their low toxicity and flammability. An investigation of possible HM tested was conducted by Rensselaer Polytechnic Institute.[3] Properties of the fluids, other than those listed below can be found in the hazardous chemicals reference guide.[4] The properties listed below were determined in the OHMSETT laboratory from samples taken during testing.

---

3. Sinclair, J.R. and W.H. Bauer. Containment and Recovery of Floating Hazardous Chemicals with Commercially Available Devices. In: Proceedings of the 1976 Conference on Control of Hazardous Material Spills. pp. 272-276

4. NFPA Committee on Hazardous Chemicals Society. Hazardous Chemicals Data 1973. National Fire Protection Association, Boston, Massachusetts, 1973. 291 pp.

	Naphtha	DOP	Octanol
Specific Gravity	0.802	0.978	0.821
Interfacial Tension ($x10^{-3}$N/m) @23°C with OHMSETT water (Salinity = 16 ppt)	10.9	11.9	9.6
Surface Tension ($x10^{-3}$N/m) @23°C	28.9	34.8	29.7
Viscosity ($x10^{-6}m^2/s$)			
@23°C	6.5	67.4	11.2
@57°C	5.0	19.4	6.8
Flash Point @20°C	38	218	81

SORBENT, GEL, AND FOAM DESCRIPTION

Sorbent C

Sorbent C is a fibrous, oil absorbent material, buoyant in water even when fully saturated with oil. Sorbent C is comparable to the material used in acoustic ceiling tiles. It is shredded and contains a considerable amount of fine dust.

Imbiber Beads

Dow Chemical Company Imbiber Beads are small (7 mm diameter), white spheres made of crossed-linked polymers of t-butylstyrene which absorb and retain hydrocarbons. The beads are oleophilic and hydrophobic. A specific gravity of 0.6 allows them to float easily. They can expand to three times their normal diameter when absorbing a good solvent. This would give an absorption capacity of 27 times the original bead volume. Dow Chemical Company recommends using the beads in packets rather than loose since they become soft and very sticky after hydrocarbon absorption.

Polyurethane Foam Cubes

The foam sorbent was reticulated, open cell, 80 pores/inch, quenched polyurethane cubes 1.9 cm per side. This type of foam cube was found to be durable and effective in absorbing hydrocarbons in previous tests at OHMSETT.

Fire Fighting Foam

FC-206, an aqueous film forming foam produced by 3M Company, was employed as the fire fighting foam. A standard mixing nozzle (obtained from a local fire station), connected to a fire hose under 5.27×10^{-4} kg/m^2 pressure and positioned in the container of concentrated foam produced a stream which shot about 6 m. The hose pressure was adequate enough to produce a 7.6 cm thick blanket of foam. A hose having a greater pressure would shoot the stream farther and probably produce a thicker blanket due to the more turbulent mixing in the nozzle.

VAPOR DETECTION EQUIPMENT

A Miran 1A Gas Analyzer and an Esterline Angus Mini-Servo strip chart recorder were positioned on the video truss during testing (Figure 6). One filtered intake was mounted on the north side, center of the main bridge, 0.3 m above the calm water (or 0.6 m) for H.C. wave conditions). The other was positioned on the south side of the auxiliary bridge on a pivot mount which could be swung to follow the boom apex (Figure 7). The pivot mount was made from 1.27 cm PVC piping. Each intake had 22.5 m of 1.27 cm diameter plastic tubing between it and the analyzer. Two 1.27 cm valves were used to open the desired intake and close the other.

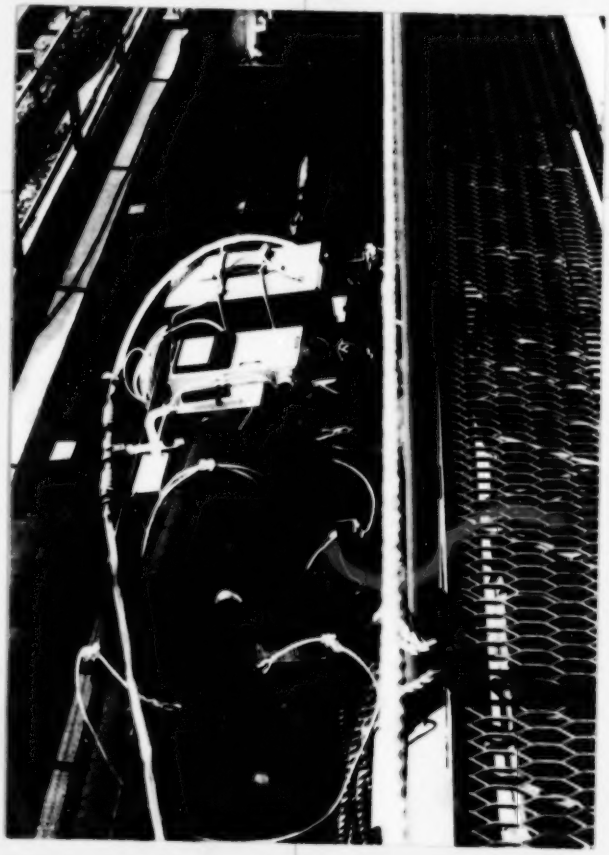


Figure 6. Vapor detection equipment mounted on the video truss.

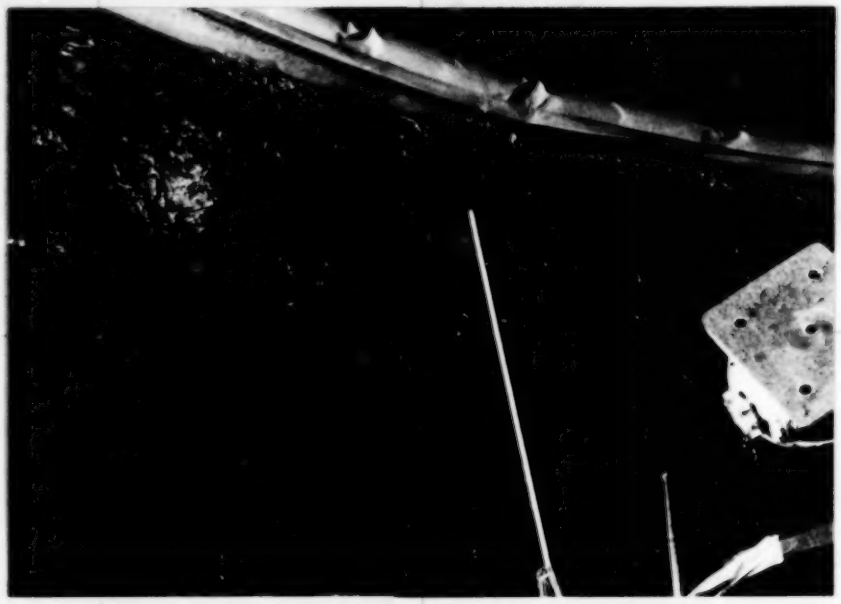


Figure 7. Vapor detection filtered inlet positioned on the auxiliary bridge with a pivot mount.

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SECTION 4

TEST PLAN AND PROCEDURES

TEST RATIONALE

To compare the tests conducted in this program with the 1975 hazardous materials program, a test matrix was written to duplicate the previous program with the addition of sorbents and fire fighting foam (Table 1). However, HM logistics required that less test fluid be used per test and some HM not be tested as much as others. So, 0.38 m^3 of HM was distributed per test instead of 1.325 m^3. If a greater amount of fluid had been distributed, a greater amount of sorbent and foam would have been needed. Also, cleanup operations would have been longer and more difficult. The smaller HM slick in the boom could have resulted in a slightly higher tow speed being required to produce shedding losses.

As the program proceeded, certain tests were eliminated from the matrix. The harbor chop wave condition caused splashover failure at 0.05 m/s for every sorbent without AFFF. It was decided that the light foam would not affect these results so the tests with sorbent and AFFF in the harbor chop were deleted. The diversionary configuration of the boom was eliminated due to the large amount of sorbent and HM a continuous slick would require. Control tests without sorbents or foam were conducted in the containment configuration for a basis of comparison with the 1975 tests.

TEST PROCEDURES

All performance testing was conducted at OHMSETT by operating contractor, Mason & Hanger-Silas Mason Co., Inc., with the guidance of U.S. EPA personnel. During all tests with naphtha, a fire fighting team was standing by with asbestos suits and fire fighting foam equipment.

BOOM TESTS

Boom tests were begun after all personnel reported to their positions with the appropriate safety equipment (e.g. goggles, respirators, gloves, hard hats). The motor on the sorbent broadcaster was started and the bridge was set in motion heading south at 0.5 kt. Distribution of the hazardous material was begun shortly thereafter at 6.3 l/s and continued for one minute.

As the north side of the bridge passed over the material, the sorbent was poured into the blower and distributed onto the slick (Figure 8). If fire fighting foam was used, it was applied seconds later by shooting it out over the sorbent and slick. About 18 liters of foam were used per test. The combination was allowed to reach the boom

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TABLE 1. PRIMARY TEST MATRIX

I. Boom Tests

Test No.	Configuration	Test Fluid	Sorbent	Waves
A-0	Containment	Naphtha	None	Calm
A-1	"	"	Cubes	"
A-2	"	"	Sorbent C	"
A-3	"	"	Beads	"
A-4	"	"	Cubes	0.3 m HC
A-5	"	"	Sorbent C	"
A-6	"	"	Beads	"
B-0	Containment	DOP	None	Calm
B-1	"	"	Cubes	"
B-2	"	"	Sorbent C	"
B-3	"	"	Beads	"
B-4	"	"	Cubes	0.3 m HC
B-5	"	"	Sorbent C	"
B-6	"	"	Beads	"
C-0	Containment	Octanol	None	Calm
C-1	"	"	Cubes	"
C-2	"	"	Beads	"
D-1	Diversionary	Naphtha	Cubes	Calm
D-2	"	"	Sorbent C	"
D-3	"	"	Beads	"
D-4	"	"	Cubes	0.3 m HC
D-5	"	"	Sorbent C	"
D-6	"	"	Beads	"
E-1	Diversionary	DOP	Cubes	Calm
E-2	"	"	Sorbent C	"
E-3	"	"	Beads	"
E-4	"	"	Cubes	HC
E-5	"	"	Sorbent C	"
E-6	"	"	Beads	"
F-1	Diversionary	Octanol	TBD	TBD
F-2	"	"	"	"

Note: During all tests tow speed will be increased until the boom begins to lose material.

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TABLE 1. (Continued)

II. Skimmer Tests*

Test No.	Test Fluid	Sorbent	Waves
A-2S	Naphtha	Sorbent C	Calm
A-3S	"	Beads	Calm
A-5	"	Sorbent C	HC
A-6	"	Beads	HC
B-2S	DOP	Sorbent C	Calm
B-3S	"	Beads	Calm
B-5S	"	Sorbent C	HC
B-6S	"	Beads	HC
C-1S	Octanol	Beads	TBD
C-2S	"	Sorbent C	Calm

*These tests are to be run immediately after the corresponding boom tests.

III. AFFF Tests - with boom (conducted on last four days)

Boom Tests

Test No.	Configuration	Test Fluid	Sorbent	Waves
G-1	Containment	Naphtha	Cubes	Calm
G-2	"	"	Sorbent C	"
G-3	"	"	Beads	"
G-4**	"	"	Cubes	HC
G-5**	"	"	Sorbent C	HC
G-6**	"	"	Beads	HC
H-1	Containment	DOP	Cubes	Calm
H-2	"	"	Sorbent C	"
H-3	"	"	Beads	"
J-1	Containment	Octanol	Cubes	Calm
J-2	"	"	Sorbent C	Calm
J-3	"	"	Beads	"
K-1	Diversionary	Naphtha	Cubes	Calm
K-2	"	"	Sorbent C	"
K-3	"	"	Beads	"
K-4*	"	"	Cubes	HC
K-5*	"	"	Sorbent C	"
K-6*	"	"	Beads	"
L-1	Diversionary	DOP	TBD	TBD
L-2	"	"	"	"

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TABLE 1. (Continued)

III. AFFF Tests (Continued)

M-1	Diversionary	Octanol	TBD	TBD
M-2	"	"	"	"

**May not be conducted because of foam mixing with the tank water.

Note: During all tests tow speed will be increased until the boom begins to lose material.

IV. AFFF Tests

Skimmer Tests*

Test No.	Test Fluid	Sorbent	Waves
G-2S	Naphtha	Sorbent C	Calm
G-3S	"	Beads	Calm
G-5S	"	Sorbent C	HC
G-6S	"	Beads	HC
H-2S	DOP	Sorbent C	Calm
H-1S	"	Beads	Calm
J-2S	Octanol	Sorbent C	Calm
J-3S	"	Beads	"
J-0	"	None	"

*These tests are to be conducted directly following the corresponding boom tests.

TBD - To be determined

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Figure 8. Sorbent C being distributed with the centrifugal blower from the main bridge.

Figure 9. I.M.E. Swiss OELA skimmer during testing with imbiber beads.

apex before tow speed changes were made. Generally, speed was increased until failure (any HM loss from the boom) was observed, then decreased until failure ceased, and then increased again to confirm the failure speed. This speed was recorded as critical tow speed (Table 2).

When DOP was used as the hazardous material, speed was decreased to below 0.5 kt to stop failure and then the critical speed was determined. Certain tests, were repeated with the same charge in the boom to observe the effect of longer mixing and absorption time.

Since there was little information available from the manufacturers of the sorbent materials as to how much to use, a trial method was adopted. Sorbent C and foam cubes were distributed until about 3/4 of the slick was covered after it reached the boom. This required two bags or 16.36 kg of Sorbent C and 0.22 m^3 of foam cubes. The fire fighting foam was distributed until slick was covered. A Dow Chemical representative suggested dosages for Imbiber Bead application. A one-to-ten ratio was used for DOP and octanol while a one-to-twenty ratio was employed for naphtha. The congealing effects on the three HM were comparable.

SKIMMER TESTS

Following boom tests with Sorbent C and Imbiber Beads, skimmer tests were conducted at mid-tank (Figure 9). The HM and sorbent in the boom was directed to the skimmer using fire hoses. The recovered material was pumped to translucent, polyethylene collection barrels. After a sufficient settling time, (approximately 2 hours), liquid levels in the barrels were measured and the water drained from the bottom. The remaining mixture of sorbent and fluid was mixed, sampled and analyzed for oil, water and solid content (Table 3). No skimmer tests were performed using foam cubes since they would have clogged the hoses and pump.

The foam cubes were recovered by nets after the test to prevent loss and mixture with the beads and Sorbent C (Figure 10). The cubes were squeezed and reused in subsequent tests. The cubes were squeezed using a hydraulically driven wringer made by Seaward International, Inc. (Figure 11). A wringer fabricated from hard rubber or wooden rollers would also be satisfactory.

VAPOR DETECTION TESTS

Prior to boom tests, the two sampling inlets were placed in position, and the analyzer and recorder were set as follows:

Analyzer		Recorder	
Path length setting	6.0*	Drum speed	4 cm/min
Slit	1 mm	Potential	1 v
Wavelength	3.42 microns		
Function switch	1A		
Gain	High		
Fine Gain	0.0		

*corresponds to a 9.75 m light path length

TABLE 2. CLEAN WATER HARBOUR BOOM TEST RESULTS

Date	Test no.	AMBIENT CONDITIONS: Air Temp. °C (°F)	Wind Speed m/s (mph)	Wind Dir.	Water Temp. °C (°F)	Test Fluid	Sorbent and Foam	Wave Cond.	Critical tow speed m/s (ft/min)	Mode of failure
5/4	A-0	8.9 (48)	5.36 (12)	N	15.0 (59)	Naphtha			0.57 (110)	Shedding
5/3	A-1	14.4 (58)	1.79 (4)	NW	16.1 (61)	Naphtha	Cubes	C		Apex extended to far beyond auxiliary bridge for adequate observation
5/3	A-1R	15.0 (59)	1.34 (3)	NNW	16.1 (61)	Naphtha	Cubes	C	0.77 (150)	Shedding aided by boom skirt fluct.
5/4	A-2	12.2 (54)	3.57 (8)	NW	15.0 (59)	Naphtha	Sorbent C		0.72 (140)	Shedding aided by boom skirt fluct.
5/4	A-3	8.9 (48)	4.9 (11)	N	15.0 (59)	Naphtha	Beads	C	0.46 (90)	Shedding
5/4	A-3R	8.3 (47)	4.9 (11)	N	15.0 (49)	Naphtha	Beads	C	0.51 (101)	Shedding
5/4	A-3RR	8.9 (48)	2.2 (5)	NNE	15.0 (59)	Naphtha	Beads	C	0.54 (105)	Shedding

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TABLE 2. Continued.

Date	Test no.	AMBIENT CONDITIONS: Air Temp. °C (°F)	Wind Speed m/s (mph)	Wind Dir.	Water Temp. °C (°F)	Test Fluid	Sorbent and Foam	Wave Cond.	Critical tow speed m/s (ft/min)	Mode of failure
5/6	A-4	22.2 (72)	3.1 (7)	NW	16.1 (61)	Naphtha	Cubes	HC	0.05 (10)	Splashover
5/6	A-5	13.9 (57)	1.8 (4)	NW	16.1 (61)	Naphtha	Sorbent C	HC	0.05 (10)	Splashover
5/4	A-6	8.9 (48)	1.79 (4)	NNE	15 (59)	Naphtha	Beads	HC	0	Splashover
5/5	B-0	11.7 (53)	0.9 (2)	W	14.4 (58)	DOP		C	0.21 (40)	Shedding
5/5	B-1	11.1 (52)	0.4 (1)	W	14.4 (58)	DOP	Cubes	C	0.28 (55)	Shedding of soaked cubes
5/6	B-2	26.7 (80)	4.9 (11)	SSE	17.2 (62)	DOP	Sorbent C	C	0.21 (40)	Shedding. Wind a factor
5/9	B-3	4.4 (40)	5.4 (12)	SE	16.7 (62)	DOP	Beads	C	0.39 (75)	Shedding
5/5	B-4	11.7 (53)	0.9 (2)	W	14.4 (58)	DOP	Cubes	HC	0.05 (10)	Splashover

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TABLE 2. Continued.

Date	Test no.	AMBIENT CONDITIONS: Air Temp. °C (°F)	Wind Speed m/s (mph)	Wind Dir.	Water Temp. °C (°F)	Test Fluid	Sorbent and Foam	Wave Cond.	Critical tow speed m/s (ft/min)	Mode of failure
5/6	B-5	27.2 (81)	6.7 (15)	SE	17.2 (62)	DOP	Sorbent	HC	0.05 (10)	Splashover
5/9	B-6	2.8 (37)	2.2 (5)	SSW	14.41 (58)	DOP	Beads	HC	0.05 (10)	Splashover
5/9	C-0	6.1 (43)	0.4 (1)	SSW	14.4 (58)	Octanol		C	0.57 (110)	Shedding
5/10	C-OR	7.2 (45)	4.9 (11)	SSW	12.2 (54)	Octanol		C	0.57 (110)	Shedding
5/10	C-1	7.8 (46)	1.8-3.1 (4-7)	SSW	12.2 (54)	Octanol	Cubes	C	0.57 (110)	Shedding
5/10	C-1R	7.8 (46)	2.2 (5)	SSW	12.2 (54)	Octanol	Cubes	C	0.62 (120)	Shedding
5/10	C-2	8.9 (48)	3.6 (8)	W	12.2 (54)	Octanol	Beads	C	0.62 (120)	Shedding
5/11	G-1	11.1 (52)	2.7 (6)	SSW	13.9 (57)	Naphtha	Cubes & Foam	C	0.57 (110)	Shedding
5/10	G-2	11.7 (53)	2.7 (6)	SSW	13.9 (57)	Naphtha	Sorbent C & Foam	C	0.62 (110)	Shedding

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TABLE 2. Continued.

Date	Test no.	AMBIENT CONDITIONS: Air Temp. °C (°F)	Wind Speed m/s (mph)	Wind Dir.	Water Temp. °C (°F)	Test Fluid	Sorbent and Foam	Wave Cond.	Critical tow speed m/s (ft/min)	Mode of failure
5/11	G-3	13.3 (56)	3.1 (7)	SW	13.9 (57)	Naphtha	Beads & Foam	C	0.72 (140)	Shedding
5/11	G-3R	13.9 (57)	2.2 (5)	SSW	13.9 (57)	Naphtha	Beads & Foam	C	0.72 (145)	Shedding
5/12	H-1	22.2 (72)	2.7 (6)	SE	16.1 (61)	DOP	Cubes & Foam	C	0.31 (60)	Shedding of soaked cubes
5/12	H-2	18.3 (65)	2.7 (6)	SE	15.6 (60)	DOP	Sorbent C & Foam	C	0.39 (75)	Shedding
5/12	J-2	13.2 (56)	0.9 (2)	SSW	14.4 (58)	Octanol	Sorbent C & Foam	C	0.57 (110)	Shedding of fluid, not sorbent
5/12	J-3	16.7 (62)	1.8 (4)	NW	15.0 (59)	Octanol	Beads & Foam	C	0.62 (120)	Shedding

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TABLE 3. I.M.E. SWISS OELA III SKIMMER RESULTS

Date	Test no.	Duration of test sec	Test fluid	Sorbent and foam	Cumulative** Sample Water m^3 (gal)	Cumulative** Sample Oil and solids m^3 (gal)	Discrete Sample % water	Discrete Sample % oil	Discrete Sample % solids	Comments
5/4	A-2S	900	Naphtha	Sorbent C	0.76 (202)	0.44 (116)	2.0	70.4	27.5	Double diaphragm pump clogged intermittently.
5/4	A-3S	300	Naphtha	Beads	0.21 (56)	0.36 (94.7)	11.2	88.8	N/A*	Used double diaphragm pump.
5/6	A-5S	600	Naphtha	Sorbent C	0.98 (260.8)	0.19 (50.8)	6.0	64.0	30.0	Waves washed material into skim.
5/9	B-3S	180	DOP	Beads	0.32 (85.7)	0.32 (84.5)	18.0	82.0	N/A*	Rotary pump used.
5/10	C-2S	180	Octanol	Sorbent C	0.18 (47.7)	0.55 (146.0)	N/A	N/A	N/A	Rotary pump used.
5/10	G-2S	240	Naphtha	Sor. C & Foam	0.46 (123.2)	0.31 (81.5)	9.2	90.8	N/A	Rotary pump used.
5/11	G-3S	300	Naphtha	Beads & Foam	0.66 (173.4)	0.45 (118.7)	11.5	88.5	N/A*	Beads very congealed.

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TABLE 3. (Continued)

Date	Test no.	Duration of test sec	Test fluid	Sorbent and foam	Cumulative** Sample Water m^3 (gal)	Cumulative** Sample Oil and solids m^3 (gal)	Discrete Sample % water	Discrete Sample % oil	Discrete Sample % solids	Comments
5/12	J-2S	135	Octanol	Sor. C & Foam	0.17 (45.4)	0.43 (114.8)	3.6	79.1	17.3	Rotary pump used.
5/12	J-3S	225	Octanol	Beads & Foam	0.40 (104.7)	0.36 (96.4)	7.3	92.7	N/A*	Rotary pump used.
5/12	H-2S	225	DOP	Sor. C & Foam	0.36 (95.2)	0.39 (104.0)	13.3	34.5	52.2	Sample taken from upper layer.
5/12	J-OS	330	Octanol		0.76 (201.0)	0.23 (99.7)	26.0	74.0	0	Control test.

*The lab analysis employs toluene, which dissolves the imbiber beads.
**The cumulative sample takes into account the discrete sample composition.

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Figure 10. Recovering polyurethane cubes with a net.

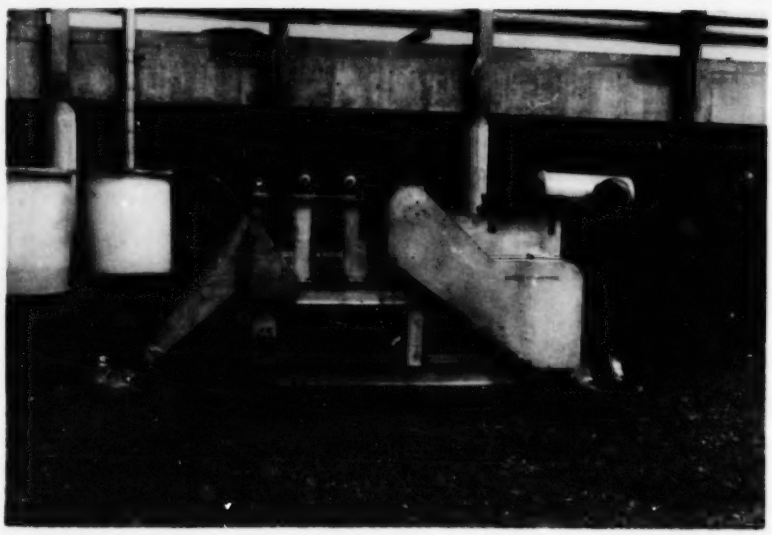

Figure 11. Seaward International, Inc. hydraulic squeezer.

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The valve to allow the main bridge inlet to sample was opened. The valve to allow the auxiliary bridge inlet to sample was closed. The recorder was turned on two minutes before testing began. After the HM slick passed completely beneath and beyond the main bridge intake and had contacted the boom, the valve positions were reversed to allow sampling above the HM/sorbent/foam mixture. The valves remained so until the boom test was terminated at the south end of the tank. The recorder was then turned off and the analyzer left on. Data were recorded and tabulated (Tables 4 through 9). Some difficulties were experienced with the recorder. When it was inoperative, a visual observation of the gas analyzer meter was made and the maximum reading was recorded.

Preliminary tests - effect of inlet tubing length on vapor detector response

An experiment was conducted to determine the effect of sample hose length on gas analyzer readings. Two hoses, 15 m and 3 m in length, were connected to a filtered inlet and the gas analyzer with valves at both ends of each hose. The filtered inlet was suspended in a jar containing a small quantity of naphtha (Figure 12). The procedures were as follows:

1. All valves were opened and readings taken.

2. The valves on the long hose were closed and readings were taken for 10 minutes.

3. The valves on the long hose were closed while simultaneously the valves on the short hose were opened. Readings were taken for 10 minutes.

4. The valve positions were reversed and readings taken again for 10 minutes.

The results were that in each case the readings remained the same--between .43 and .46 absorbance. The conclusion was than a long hose does not affect results.

Another test, for response time, was conducted by placing a filtered intake on the long hose over the naphtha and recording the time required before an increase in concentration registered on the recorder. The reading was stabilized and the intake removed from the jar. The time for the recorder to return to the ambient air reading was also noted. The results showed a 10 second lag existed between placing the intake in the jar and an increase on the recorder. More than a minute was required to return to ambient readings after the intake was removed.

The conclusion was that only local maximums could be considered as accurate indicators of vapor concentrations.

Equipment checks during the test period

Function checks on the gas analyzer were run on a daily basis to ensure proper functioning. Between test runs, the analyzer readings were observed, though not recorded, to ensure the meter returned to the 0.16-0.175 Absorbance range (ambient air reading). Clogging of the filters on the inlets with Sorbent C dust or Imbiber Beads was periodically monitored using a beaker of HM directly beneath the filter and

TABLE 4. VAPOR DETECTION TEST DATA USING NAPHTHA

Test no.	Sorbent	Absorbance HM	Absorbance HM and Sorbent	Concentration (ppm) HM	Concentration (ppm) HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
A-0	None	.26	.40	11	28	+17	Crosswind from east to west.
A-1	Cubes	Inop	.40	N/A	28		No HM filter, no tests taken over HM. Sample inlet for HM/S was about 20' from apex of boom and collected slick. Boom was shortened for other tests.
A-1R	Cubes	NO DATA		N/A			No new sorbent broadcast.
A-2	Sorbent C	NO DATA - RECORDER MALFUNCTION					
A-3	Beads	.30	.37	15	24	+9	Rained during test. Boom shifted west of the HM/S sample inlet.
A-3R	Beads	.32	.42	18	30	+12	Slick past filter when test began. Imbiber beads already on water.
A-3RR	Beads	.23	.28	8	13	+5	Imbiber beads already on the slick. No new HM distributed.

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TABLE 4. (Continued)

Test no.	Sorbent	Absorbance HM	Absorbance HM and Sorbent	Concentration (ppm) HM	Concentration (ppm) HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
A-4	Cubes		DATA NOT RECORDED				0.3 m HC.
A-5	Sorbent C	.119	.20	3	4	+1	Bridge speed very slow. 0.3 m HC.
A-6	Beads	.18	.42	2	30	+28	Each filter placed 2 ft. above calm water surface - for 0.3 m HC. Slick was at apex before test began.

TABLE 5. VAPOR DETECTION TEST DATA USING NAPHTHA AND AFFF

Test no.	Sorbent	Absorbance: HM	Absorbance: HM and Sorbent	Concentration (ppm): HM	Concentration (ppm): HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
G-1	Cubes	.32	.24	18	9	-9	Wind blowing to south.
G-2	Sorbent C	.22	.30	6	15	+9	Protective cover put over filter. Wind direction to east. Slick collected on west.
G-3	Imbiber Beads	.22	.36	6	23	+17	Slick built up on west side of tank. Break in foam occurred.
G-3R	Imbiber Beads	N/A - No new Sorb or Im Beads	.26		11	N/A	Irregular foam coverage of slick (patches). HM/S filters encased in aluminum pipe to stiffen PVC pipe.

TABLE 6. VAPOR DETECTION TEST DATA USING DOP

Test no.	Sorbent	Absorbance HM	Absorbance HM and Sorbent	Concentration (ppm) HM	Concentration (ppm) HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
B-0	None	.20	.20	6	6	0	More HM distributed than test plan called for.
B-1	Cubes	.18	.19	3	4	+1	Filters at 2 ft. instead of 1 ft. above water.
B-2	Sorbent C	.23	.58	9	59	+50	Slick moved to west side of tank. Had changed filter prior to run. Filter probably contaminated.
B-3	Beads	.25	.27	12	15	+3	HM/S pipe lengthened to 12 ft. Recorder failure. Observed max. and recorder manually. Wind blowing to north. Temp 38°F. HM/S filter adjusted over slick.
B-4	Cubes	.16	.19	0	4	+4	Pump switch off during part of experiment. Boom apex did not move directly under filter.
B-6	Beads	.16	.165	0	.4	+.4	Same slick from a previous run was used, therefore slick of plain HM did not pass under the HM filter-wind speed minimal at filter.

TABLE 7. VAPOR DETECTION TEST DATA USING DOP AND AFFF

Test no.	Sorbent	Absorbance HM	Absorbance HM and Sorbent	Concentration (ppm) HM	Concentration (ppm) HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
H-1	Cubes	.24	.26	11	14	+3	Temperature 78°F.
H-2	Imbiber Beads	.21	.23	7	10	+3	Wind blowing lightly to north.

TABLE 8. VAPOR DETECTION TEST DATA USING OCTANOL

Test no.	Sorbent	Absorbance HM	Absorbance HM and Sorbent	Concentration (ppm) HM	Concentration (ppm) HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
C-O	None	.21	.24	7	10	+3	
C-1	Cubes	.22	.22	8	8	0	Brisk wind blowing to south (generally). Cold day. Slick was well dispersed when passing first filter.
C-2	Imbiber Beads	.18	.20	2	6	+4	Boom shifted to west of centerline of tank.

TABLE 9. VAPOR DETECTION TEST DATA USING OCTANOL AND AFFF

Test no.	Sorbent	Absorbance HM	Absorbance HM and Sorbent	Concentration (ppm) HM	Concentration (ppm) HM and Sorbent	$C = C_{HM\&S} - C_{HM}$ (ppm)	Comments
J-2	Sorbent C	.20	.21	6	7	+1	Filter failed test - no time to change.
J-3	Beads	.22	.24	8	14	+6	

monitoring the readings. The beaker was held in place for one minute or until concentration readings had leveled off.

The equipment checks were interpreted as follows:

1. A pronounced increase in absorbance was considered as an accurate indication that some flow through the filter was occurring.

2. If both filters showed nearly the same absorbance readings, it was assumed that both filters were essentially free from clogging. The filter near the sorbent distributor was felt to be much more susceptible to clogging, since dust particles were swirling near it. Therefore, it was expected that a marked difference between the control test absorbance readings for the two filters would indicate clogging.

3. The actual value of the absorbance readings was not of interest since temperature could not be controlled and had a significant effect on the volatilization of control samples and hence on the absorbance readings.

Using these criteria, it was found that clogging of filter intakes did not occur in most tests.

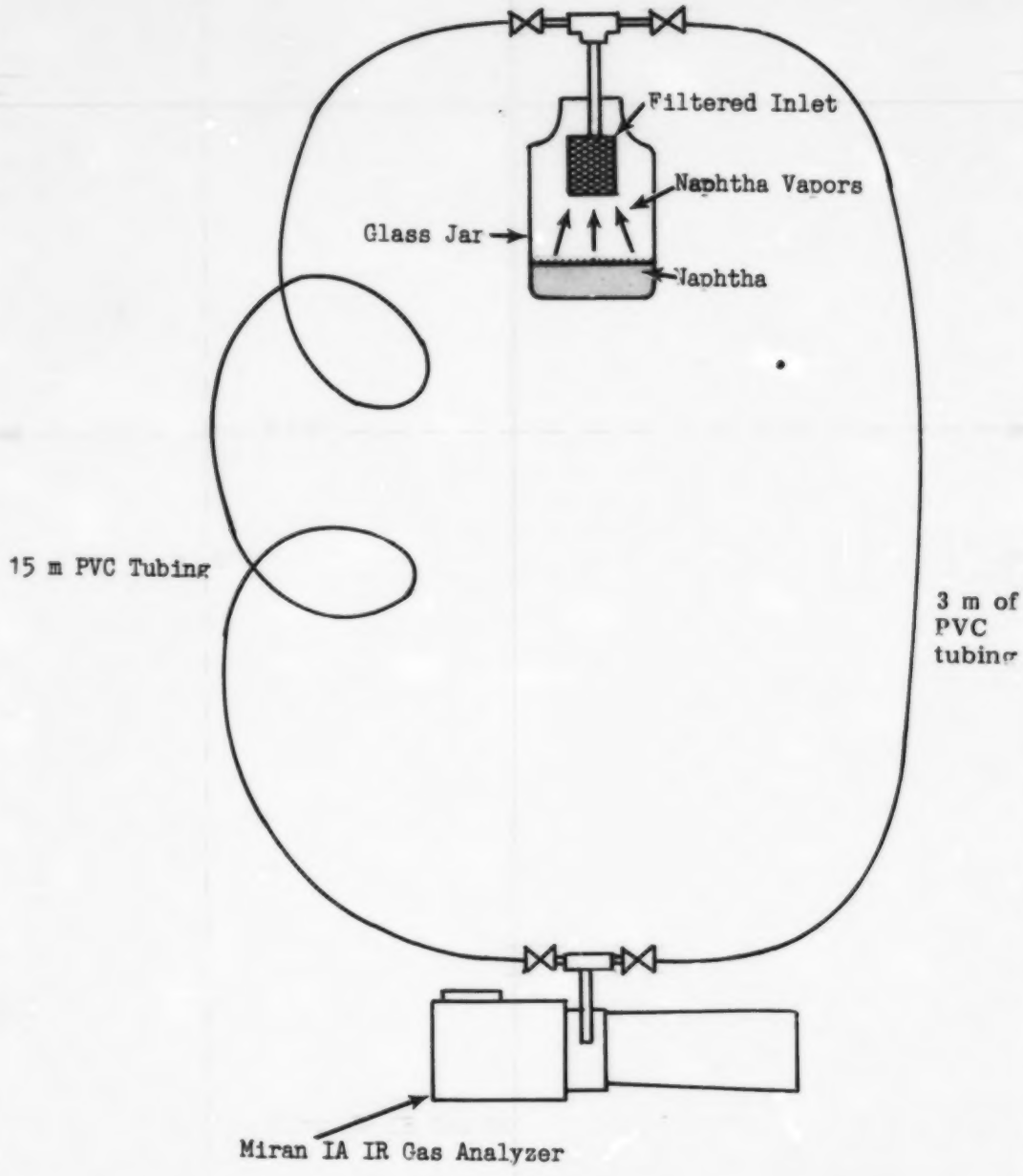

Figure 12. Vapor detection equipment arrangement for control tests.

SECTION 5

DISCUSSION OF RESULTS

BOOM TESTS

As shown in the charts (Figures 13, 14, and 15), the boom contained a pure HM slick to a higher tow speed in these tests compared to the 1975 tests. This could be attributed to bolting the boom directly to the tow points rather than tying them with chain bridles as done in 1975. This served to increase boom stability. The increase of boom stability was required in many of the calm water runs in this test program because shedding did not occur until higher tow speeds were reached. The results in harbor chop wave conditions (Figures 16 and 17) were comparable to the 1975 test results. The smaller amounts of HM used in these tests produced a smaller slick which did not extend as far forward from the boom floatation. This could have caused the slick to be protected from the shedding effect of the water passing beneath the boom until a higher tow speed was reached. The observer of boom failure in the 1975 tests was not the observer in the 1977 tests. It is possible that there were differences in their subjective decisions on how much oil loss constituted boom failure.

An unexpected benefit was observed when the foam cubes were used as the sorbent material on naphtha. The boom was towed up to 0.75 m/s without losses. At that speed the boom skirt was flexing and the boom floatation element was about to submerge, so the test was halted. Without sorbent, naphtha shed from the boom at a tow speed of 0.5 m/s. The reason for this increase in performance was the test fluid not absorbed into the foam cubes laid on the surface between the cubes and was thus protected from shedding. The cubes floated approximately 0.3 cm out of the water and 1.6 cm in the water. This formed pockets of refuge for the test fluid from the water current passing beneath the boom. Through the underwater windows it was seen that the underwater portion of the cubes prevented the interfacial shearing force from reaching the naphtha.

This type of shedding protection did not occur with Sorbent C since the particles did not extend much below the surface. The critical tow speed for DOP shedding also increased when the foam cubes were applied. The cubes which soaked in DOP shed as large droplets would have. A more buoyant cube would probably perform better with DOP.

Octanol did not act the same as naphtha with the cubes. The critical tow speed with cubes did not differ much from the tests without sorbent. It is possible that the cubes were not as well squeezed during the latter part of the test program when octanol was used as the beginning. Also, some Imbiber Beads from previous tests mixed with and clung to the cubes, closing pores and thus preventing the octanol from being absorbed into the cubes.

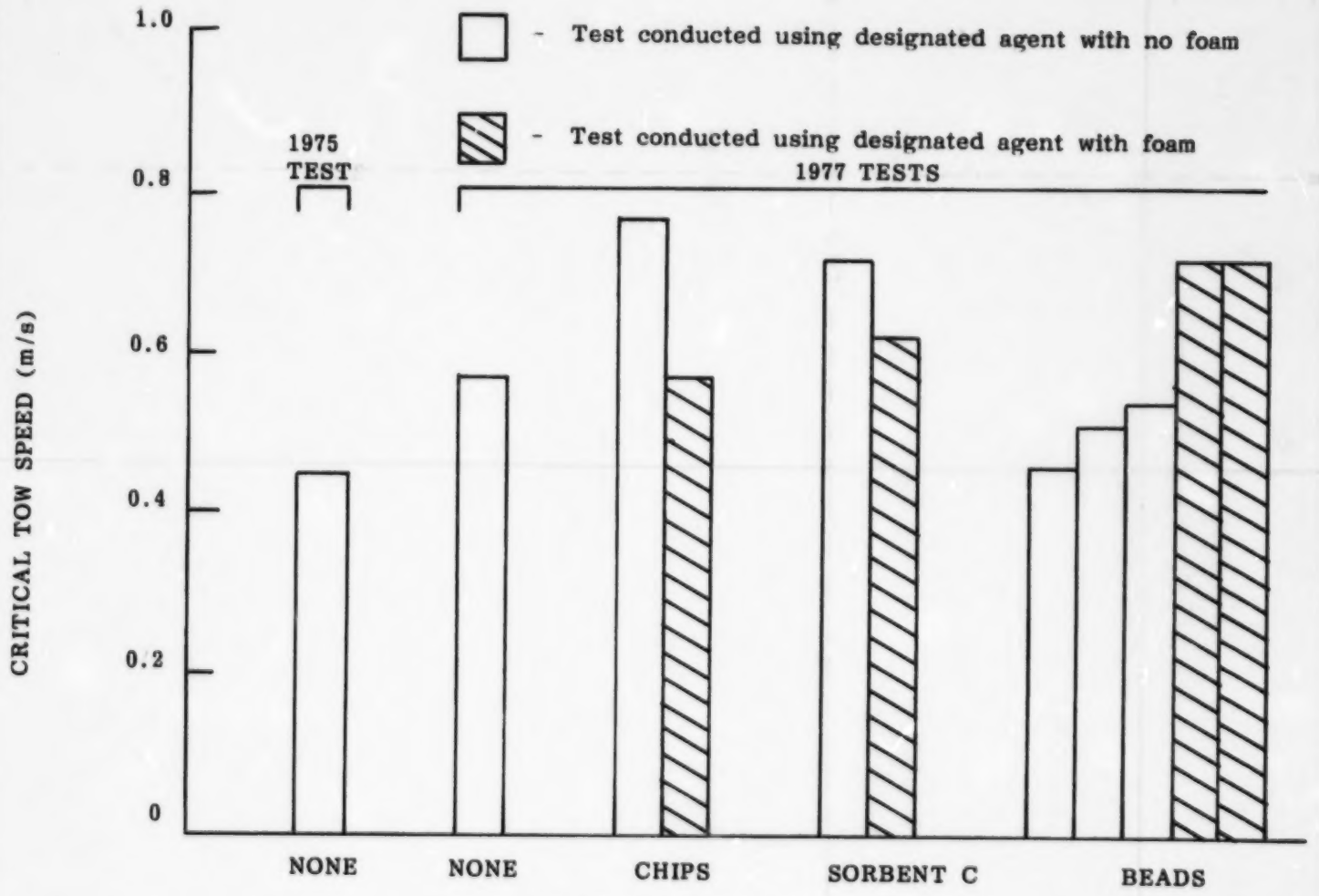

Figure 13. Clean Water boom performance in calm water using naphtha.

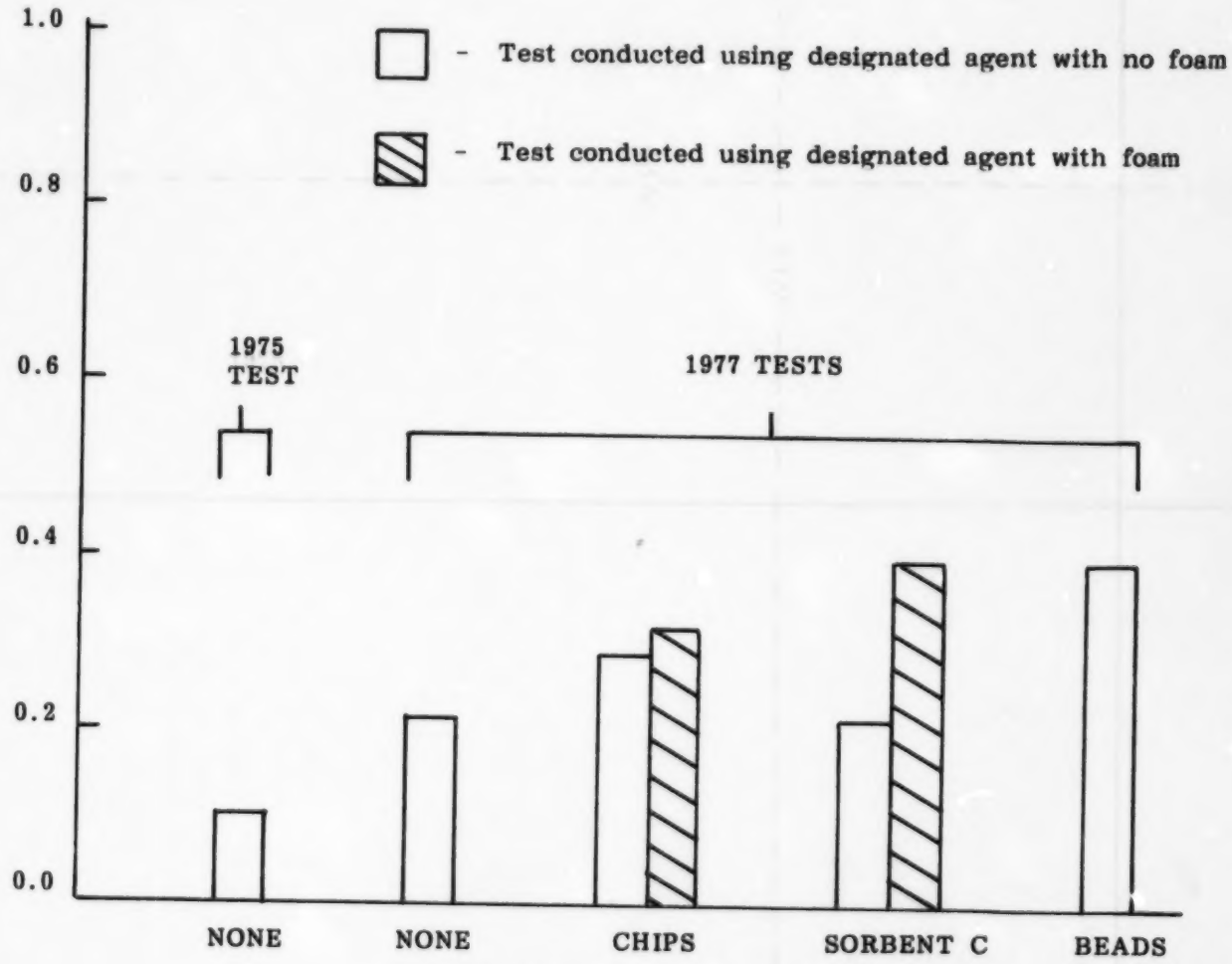

Figure 14. Clean Water boom performance in calm water using DOP.

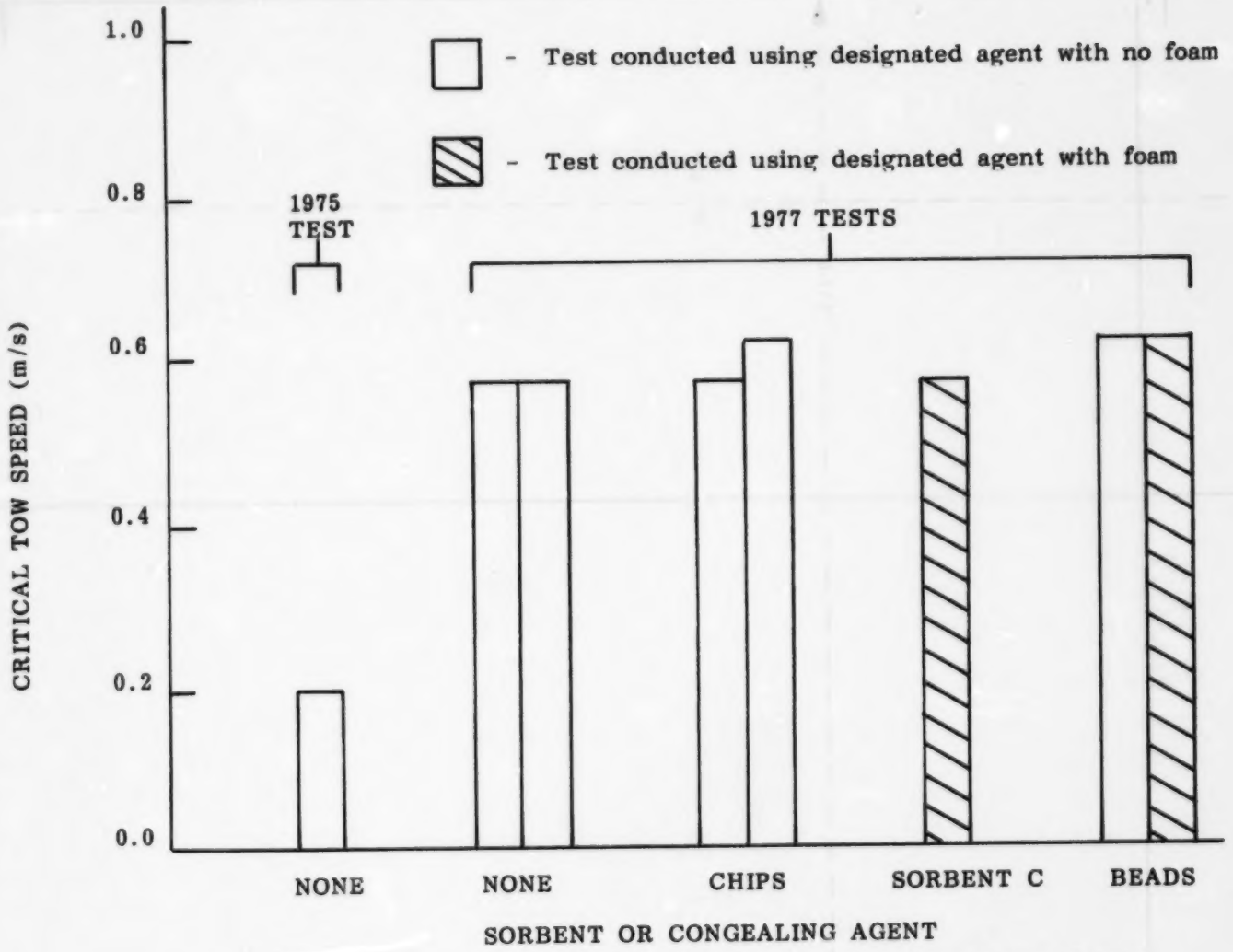

Figure 15. Clean Water boom performance in calm water using octanol.

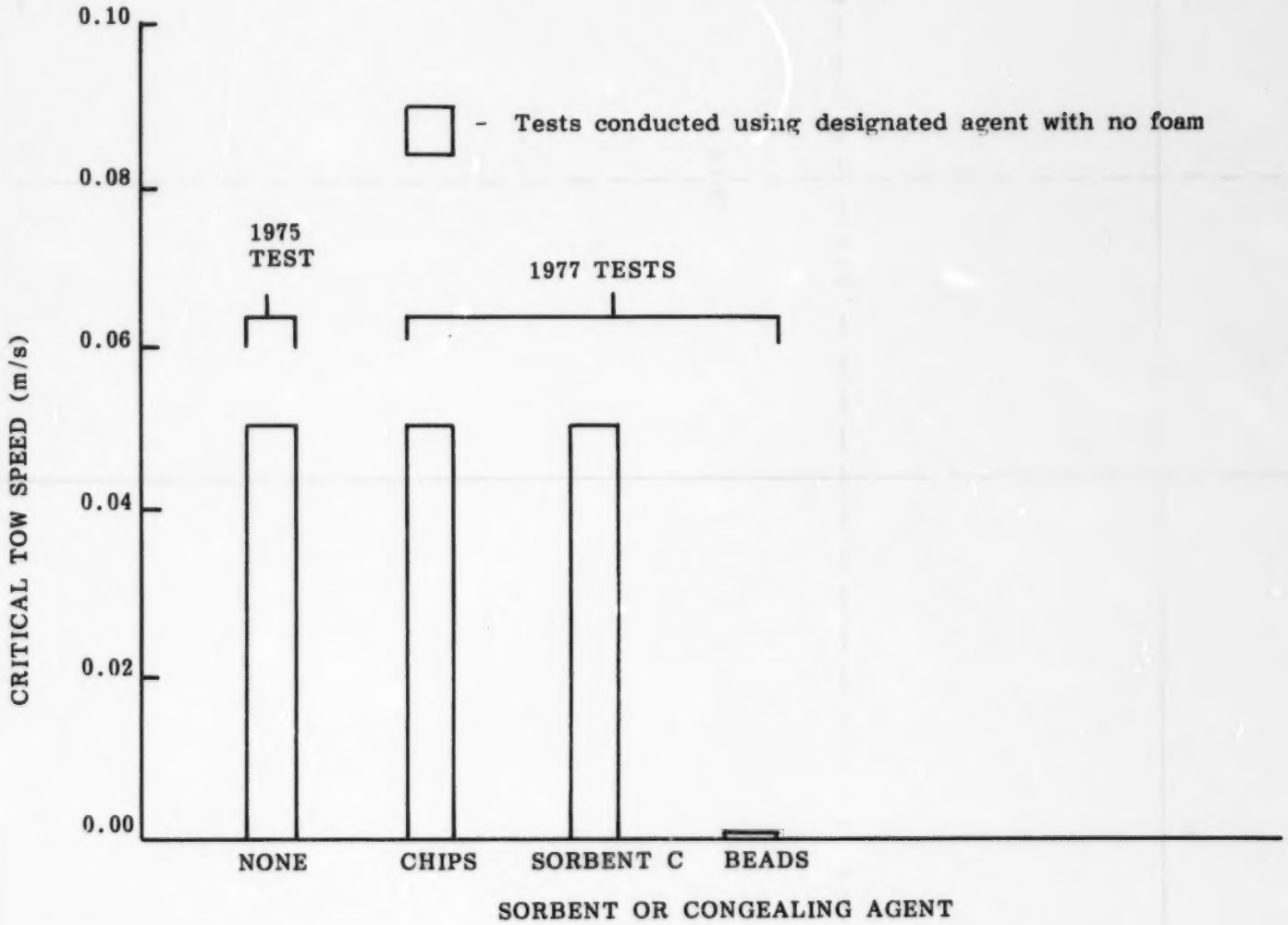

Figure 16. Clean Water boom performance in harbor chop using naphtha.

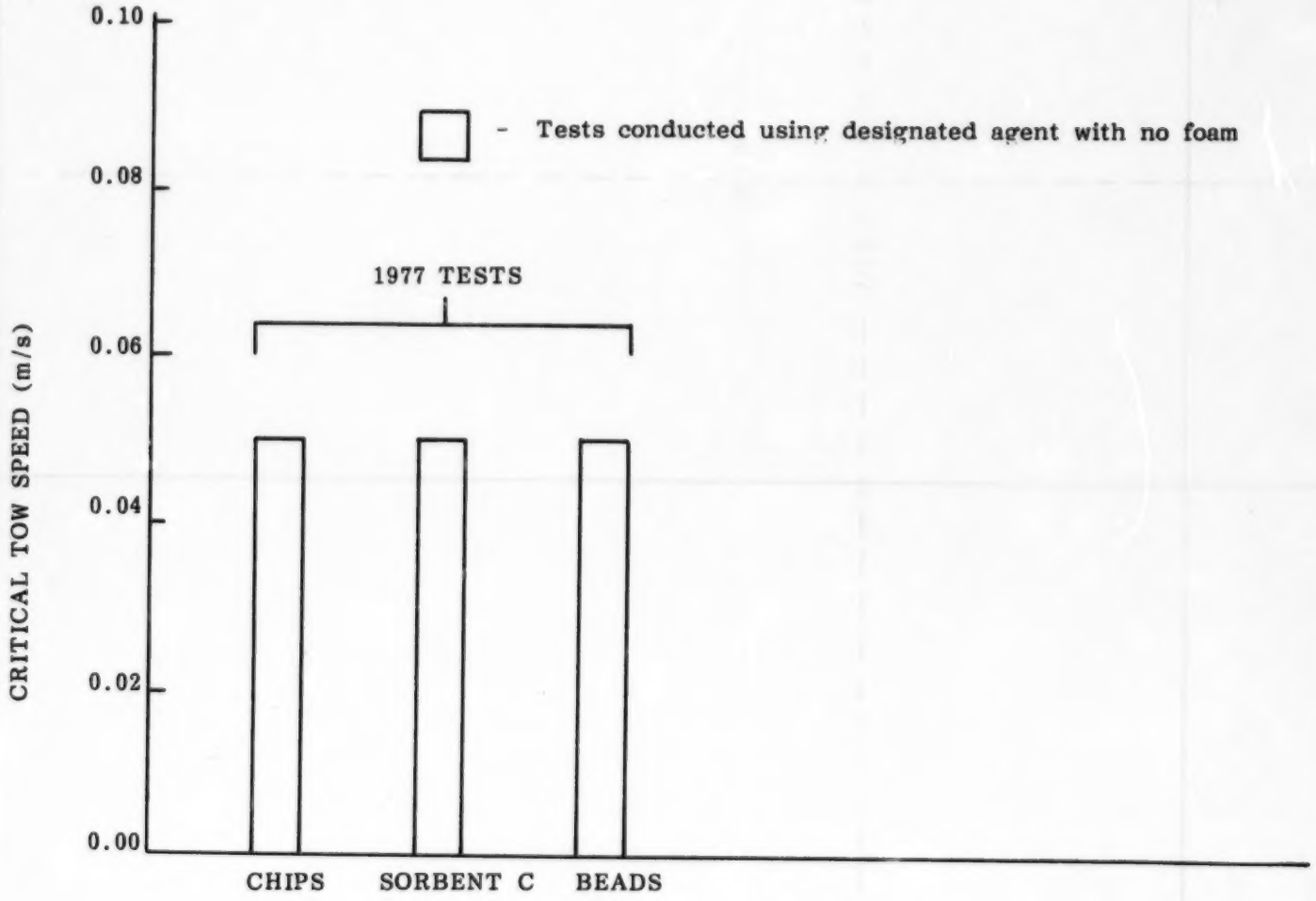

Figure 17. Clean Water boom performance in harbor chop using DOP.

Although the polyurethane foam material was not expensive ($0.50/m^2), the cutting of the cubes was. A larger cube would probably be more cost effective. The sorbent material most easily distributed and accounted for afterwards was the foam cubes.

The results obtained when employing Sorbent C showed an increase in the boom's ability to retain HM. Since the suspension of fibers in a liquid can reduce turbulent drag,[2] one of the benefits of the fine particles in the Sorbent C could have been such an effect. This would have deferred the formation and release of oil droplets from the slick due to turbulence at the oil/water interface to a higher tow speed. The product also acted as a buoyant sorbent which prevented shedding.

The Imbiber Beads performed best on DOP and worst on naphtha. Given enough Imbiber Beads and a sufficient residence time, the HM slick could have been made into a solid buoyant sheet and most probably contained by a boom at tow speeds above 2 knots. However, this would be impractical, if not impossible in field use. A 100 m^3 spill would require about 10 m^3 of beads well applied and mixed.

The sorbent and beads were often distributed onto the water surface and not onto the HM slick. This resulted in patches of dry Sorbent C or cubes and white clumps of sticky beads. This was caused by the air from the blower displacing the slick and then distributing the materials on the water. Lingering too long with the blower outlet in one position would give this results. However, if the material was not directed downward onto the slick, the wind could carry much of material off to one side.

Some test results indicate a higher critical tow speed is attainable using AFFF and sorbent rather than sorbent alone. Perhaps the foam causes the sorbent to become wetter or absorb more oil and thus stave off shedding.

The boom performance deteriorated slightly over the 12 days in the water. The boom skirt which originally began flexing at 0.65 m/s, began at 0.55 m/s by the end of the test. The flexing would periodically change the flow pattern of the water passing beneath the boom and thus eventually affect shedding. Periodic shedding which followed the frequency of skirt flexure only occurred at tow speeds above 0.7 m/s.

When substantial shedding had begun at about 0.3 kt above the critical tow speed, shedding would not stop until tow speed was reduced well below the critical speed (about 0.2 kt below). Shedding would begin again when the tow speed was increased to the critical tow speed. The churning and separating of the test fluid took less to keep it going than to start it.

SKIMMER TESTS

The use of sorbents prevented continuous flow of HM into the skimmer during calm water tests. A boat hook was used to submerge the skimmer weir so the skimmer well would not empty, causing the pump to draw air. This was not necessary when testing in a harbor chop condition because the waves washed fluid into the skimmer. In addition, Sorbent C clogged the double diaphragm pump, so a rotary pump was substituted. These equipment and procedural changes prevented overall comparison between these skimmers tests and the ones conducted in 1975. The one test which could be compared (A-5S) to a 1975 test showed a higher percentage water intake,

83.7% vs. 74.9%, and a lower recovery rate, 1.96 l/s vs. 5.7 l/s. This is probably due to the Sorbent C being mixed in with the HM. It absorbed some water and was harder to pump than HM alone. The results obtained using the I.M.E. skimmer are also very operator-dependent which makes comparisons of tests difficult.

Using sorbents substantially reduced HM and water emulsificiation or prompted fast separation of the two fluids. The skimmer test run with only octanol (J-0-S) resulted in 26% water in the sample taken from the barrel. Water content in samples from test runs with Sorbent C and Imbiber Beads resulted in 3.6% and 7.25% respectively.

Cleanup effort was substantially increased due to the use of sorbents. Imbiber Beads clung to everything they touched including skin and clothing. Sorbent C had to be hosed off the decks and driven from the bridge tow cable trays. The foam cubes had to be recovered with nets and stored in barrels--a very time consuming operation. Thought should be given to the special cleanup operations required if sorbents are to be used in the field.

VAPOR DETECTION TESTS

DOP and octanol have low vapor pressures and the recorded changes in vapor concentration were very small. The experimental variations far outweighed the changes in concentration noted for DOP and octanol. No conclusions will be drawn from the experimental results for these two hazardous materials.

The naphtha results consistently indicate that the vapor concentration above the slick was higher following the addition of sorbent, however, the experimental results do not necessarily indicate that the addition of the sorbent was the cause of the increase.

The following observations indicated that other factors contributed to or totally caused the observed results:

1. Test A-0 was conducted without adding sorbent, HM filter was 11 ppm naphtha, HM/sorbent filter was 28 ppm naphtha. Ideally, these readings should be the same.

2. When the HM was distributed, an irregular pattern usually formed with splotches of HM interspersed in the water. In this condition, the slick passed under the HM filter. After sorbent was spread on the slick and the HM and sorbent had collected in the boom, an unbroken HM/Sorbent layer was present on the water. The HM/Sorbent slick remained in this condition beneath the second filtered inlet. The HM/Sorbent filter and the slick also had no velocity relative to each other.

3. The sorbent was broadcast onto the slick close to the HM filter head. The broadcaster (blower) created considerable air turbulence, was operated manually and its height and time in operation were not the same for every test.

4. Some of the sorbent material adhered to the HM filter head and possibly restricted flow.

5. If a filter was not clogged and a reading was observed, the absorbance value could not be compared directly to other readings since the analysis depended upon temperature, and the temperature could not be held constant throughout testing.

The following observations indicated that variations in test conditions existed which were on the order of magnitude of the concentration changes that were observed:

1. Filter control tests (Table 10) done on 11 and 12 May yielded results which showed differences in concentrations between the two filters from 2 to 13 ppm. The concentration differences for the actual naphtha tests were of like magnitude (A0, +17 ppm; A3, +9; A5, +1; A6, +28; G1, -9; and G3, +17).

2. The HM/Sorbent filter reading varied considerably for the repeated run A3, A3R, and A3RR. The vapor concentrations were 24, 30, 13 ppm, respectively. No new sorbent or HM was distributed for these tests so only the HM/Sorbent filter should have detected vapor. The HM filter, however, registered from 8 to 18 ppm.

The following observations point to potential sources of error:

1. Wind velocity was not constant. Wind velocity was measured about 3 m above the water surface and perhaps did not accurately reflect the velocity at the surface.

2. Initially, the HM/Sorbent filter was in a fixed location, centered on the long axis of the tank. Often the boom shifted to one side of the tank, leaving the HM/Sorbent filter over water instead of the material contained by the boom.

Only one test (G-1) with fire-fighting foam resulted in a depression in vapor concentration between the two intakes rather than an increase.

When using sorbents in the recovery of hazardous materials, the disposal, storage, or refurbishment of the sorbent should carefully be studied. Dow Chemical Company is currently conducting tests to determine the evaporation rate of recovered materials from sorbents. Although the concentration of vapors above a naphtha slick does not increase appreciably when sorbent is added, the material will rapidly evaporate from the same sorbent while suspended in air. This could create an air pollution or explosion hazard.

Laboratory tests should be conducted on more volatile materials than DOP and octanol. Field tests could then be used to corroborate the results. Field tests should be set up such that the HM slick does not have a velocity relative to the vapor sampling filter. The HM slick vapor intake was mounted on the north end of the main bridge and sampled the vapor as it passed over the slick. The sorbent/foam/HM intake was positioned in the apex of the boom and remained above the mixture for a much greater time period. A boom partitioned lengthwise with plain HM on one side and the sorbent/foam/HM slick on the other side could solve the discrepancy if no vapor intermixing could be assured.

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TABLE 10. FILTER CONTROL TESTS

Date & Time	Hazardous Material	Absorbance*/Vapor Concentration ppm HM Filter	HM/Sorbent Filter
11 May 1977 Before test runs 0815 to 0845	Naphtha	.26/11	.32/18
11 May 1977 Following test G-1	Naphtha	.60/51	.54/44
Following test G-3	Naphtha	.40/27	.28/14
12 May 1977 Pre Test Filter	Naphtha	.54/44	Not done due to HM in water below filter. Would have influenced reading.
After test J-3	Naphtha	.72/44	.74/66
After test J-3	Octanol DOP	.26/14 .22/8	.22/8 .22/8

*Absorbance is non-dimensional.

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OPERATION DISCUSSION

The blower outlet tube, used to distribute sorbent, became partially clogged with congealed Imbiber Beads. The foam cubes left some test fluid on the walls of the tube as they were blown from the fan. In subsequent tests, the Imbiber Beads contacted this fluid and clung to the walls. This did not affect this test. However, if another week of testing had been required, the problem would have caused a temporary shutdown to clean the blower unit.

The vapor detection equipment could not be left outside in bad weather, even with a covering. This required setting it up and breaking it down every day and each time rain threatened.

The distribution of Sorbent C from the blower produced a large amount of dust. This dust collected on the vapor detector filters, causing some minor clogging. Metal covers, open at the bottom, were fabricated and placed over the filters to protect them. These seem to work well. Filters were also changed periodically to minimize the degree of clogging.

APPENDIX A

OHMSETT TEST FACILITY

Figure A-1. OHMSETT Test Facility.

GENERAL

The U.S. Environmental Protection Agency is operating an Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey (Figure A-1). This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control of oil and hazardous material spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203 metres long by 20 metres wide and with a water depth of 2.4 metres. The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a force up to 151 kilonewtons, towing floating equipment at speeds to 3 metres/second for at least 45 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil or hazardous materials on the surface of

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the water several metres ahead of the device being tested, so that reproducible thicknesses and widths of the test fluids can be achieved with minimum interference by wind.

The principal systems of the tank include a wave generator and beach, and a filter system. The wave generator and adsorber beach have capabilities of producing regular waves to 0.7 metre high and to 28.0 metres long, as well as a series of 1.2 metres high reflecting, complex waves meant to simulate the water surface of a harbor or the sea. The tank water is clarified by recirculation through a 0.13 cubic metre/second diatomaceous earth filter system to permit full use of a sophisticated underwater photography and video imagery system, and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built-in skimming barrier which can move oil onto the North end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume, or 9842 cubic metres is filtered and treated until it meets all applicable State and Federal water quality standards before being discharged. Additional specialized treatment may be used whenever hazardous materials are used for tests. One such device is a trailer-mounted carbon treatment unit for removing organic materials from the water.

Testing at the facility is served from a 650 square metres building adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test fluids and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a permanent staff of eighteen multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology, and overall project direction.

For additional information, contact: John S. Farlow, OHMSETT Project Officer, U.S. Environmental Protection Agency, Research and Development, IERL-Ci, Edison, New Jersey 08817, 201-321-6631.

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